U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

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RADIOSONDE SET AN/DMQ-6

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Abstract

Engineering flight tests were made on a system which included Radiosonde Set AN/DMQ-6, the ARCAS rocket, and Rawin Set AN/GMD-2. Temperature data were obtained with rod thermistors and bead thermistors. Data were obtained on a high-altitude hypsometer pressure sensor under development. Wind data were obtained and evaluated, and altitude data derived from the AN/DMQ-6 and Rawin Set AN/GMD-2 were compared with those obtained with the AN/FPS-16 radar. The altitude layer over which the data were obtained was between 80,000 and 210,000 feet. The test procedure used was that described in USASRDL Technical Report 2171.

Analysis of data obtained indicates useful temperature- and wind-data to 190,000 feet. Altitude data showed agreement within one percent or better with radar data.

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FORT MONMOUTH, NEW JERSEY

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RADIOSONDE SET AN/DMQ-6

INTRODUCTION

Radiosonde Set AN/DMQ-6 was designed for rocket-parachute operation to provide wind data and temperature information from an altitude of about 220,000 to 80,000 feet. On completion of the development of a high-altitude hypsometer pressure sensor, pressure data will also be included.

BACKGROUND

Experimental models were designed and constructed at this Laboratory which, in performance, are similar to Radiosonde AN/AMQ-9. Engineering-test models were procured on contract, with the U. S. Air Force Cambridge Meteorological Laboratory, Atomic Energy Commission - Sandia Corporation, U. S. Weather Bureau, and White Sands Missile Support Activity participating.

On completion of a series of initial flight tests, it became apparent that there were certain deficiencies in the temperature-sensor exposure device. Remaining units were modified by extending the length of the temperature-sensor mount from 3 inches to a total of 5 inches out from the base of the nose cone. The mount, as used in these tests, is folded back on itself and, being a spring-loaded device, is depressed into the nose-cone base and held there when the instrumented nose cone is placed on the parachute compartment of the rocket motor. In order to prevent thermistor breakage at rocket-nose-cone separation, a pressure-activated delay mechanism was incorporated that was designed to delay the exposure of the temperature sensors to the atmosphere until about ten seconds after separation. These mechanisms had proved to be satisfactory on previous flights performed at the Atlantic Missile Range, Florida.

Five radiosondes sent to the U. S. Air Force Meteorological Laboratories were flight-tested at the Santa Rose test site, Eglin Air Force Base, Florida, with members of this Laboratory participating. Valuable radar support was provided, and an opportunity was presented to obtain upper wind comparisons with the Robin falling-sphere tests made on the same day the AN/DMQ-6 was flight-tested.

Four additional flights were made at the Pacific Missile Range, Point Mugu, California, in order to obtain engineering data on a hypsometer-pressure sensor as well as on temperature sensors. Again, excellent radar and ground equipment support was provided, permitting this Laboratory to obtain valuable additional engineering data.

DESCRIPTION

Radiosonde Set AN/DMQ-6 (Fig. 1)

The radiosonde is used to sound the atmosphere from 220,000 to 80,000 feet to provide wind data, temperature, and pressure data. It is rocket-borne from launch to 220,000 feet, and parachute-borne thereafter to

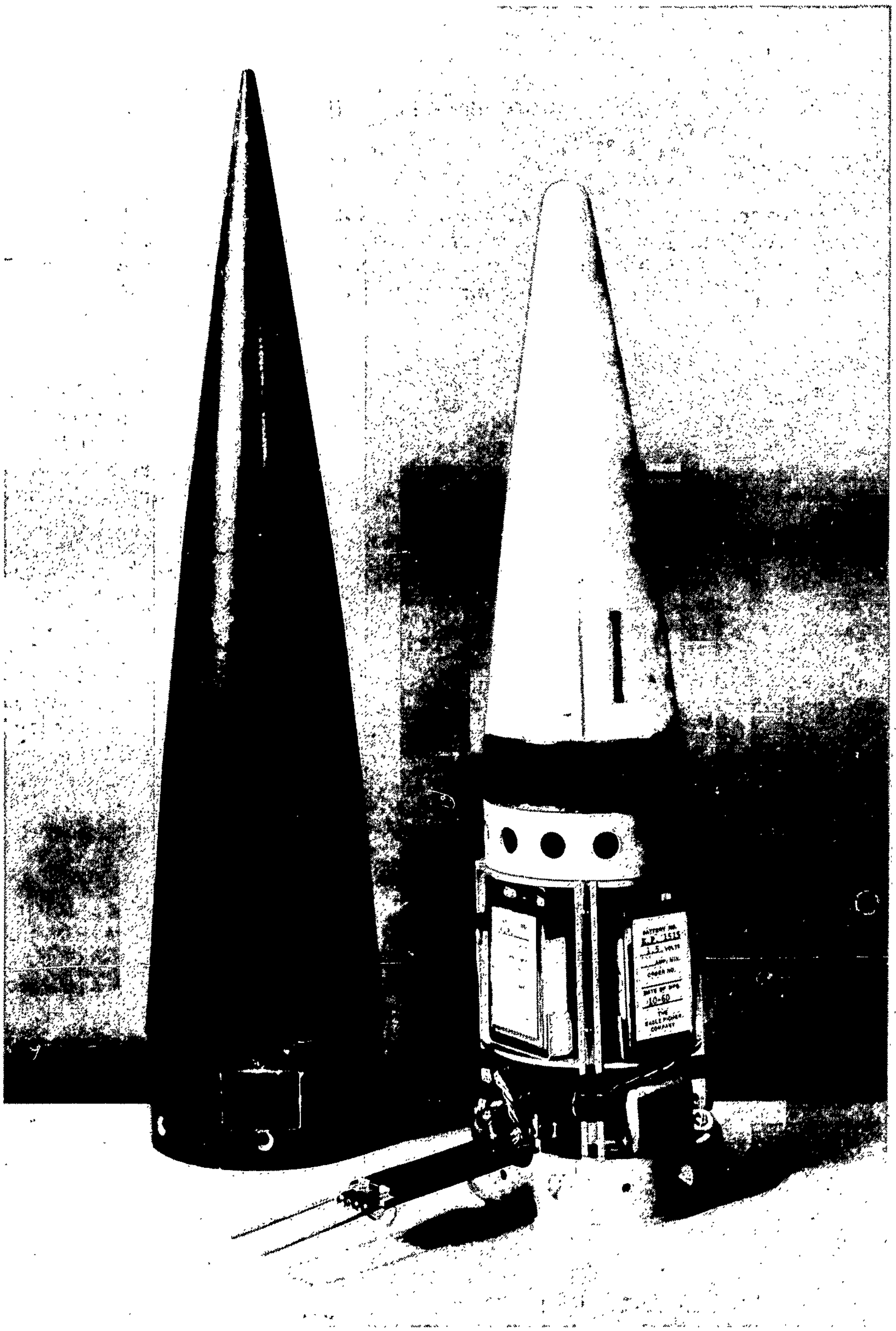


Fig. 1. Radiosonde Set AN/DMQ-6 and Nose Cone

line-of-site impact. The electronic components are encapsulated in foam plastic of 12 lbs/ft^3 density; the total weight, including nose cone, is 7.25 lbs. The radiosonde contains a chamber 2 inches in diameter by 3-3/4 inches in length for housing the hypsometer. A 4-channel time-shared commutation system provides for inputs for up to four variable resistance-type sensors. The nose cone is always attached to the radiosonde. The radiosonde consists of the following components:

1. Plastic Nose Cone and Metal Baseplate

2. 1690-mc Transmitter and Antenna. The power output varies from 0.5 to 1 watt, and the transmission is frequency-modulated cw. A helical-slot antenna provides for tracking the radiosonde during rocket ascent through parachute descent. The transmitter is ±150-kc frequency modulated, with an 81.94-kc ranging subcarrier as well as with -300-kc telemetry pulses.

3. Ranging Receiver. The 3-tube superregenerative-type receiver consists of a 403-mc oscillator, a 600-kc quenching oscillator, and an 81.94-kc tuned amplifier. It is used to detect the ranging subcarrier from an amplitude modulated 403-mc carrier generated at the AN/GMD-2 pedestal. The received subcarrier is then used to frequency modulate the 1690-mc carrier, providing, through the receiving system, range-change data throughout the flight. The 1690-mc antenna and transmitter assembly is coupled to the receiver so as to form the 403-mc antenna system.

4. Telemetry Oscillator. A transistor blocking oscillator operating from a 1.35V battery provides 1V negative pulses 100 μsec wide at a rate varying from 10 pps to 200 pps, with an input resistance range from one megohm to zero resistance. A maximum of five microwatts is dissipated through the input resistance.

5. Power Source. Six-volt primary input from four 1.5V Eagle Picher 1515 batteries at a current drain of 1.5 amperes provides operation for a minimum of 2.5 hours. Plate voltage is obtained through a 6V to 115V transistor converter. A separate 1.35V battery is used for the blocking oscillator power. When the hypsometer is installed, four EP-1525 batteries are substituted, operating at a current drain of 3 amperes or more for a minimum of 2.5 hours.

6. Sensor Mount and Time Delay (Fig. 2). A folding-type sensor mount is used to expose up to four resistance variable sensors to the atmosphere during parachute deployment. The sensor mount is folded into the nose cone at the base of the radiosonde and held in place by the parachute compartment of the rocket during rocket ascent. At peak altitude and before separation, a bellows assembly expands, locking the mount within the nose cone for ten seconds after separation. At separation, the air trapped within the bellows is allowed to leak out, contracting the bellows and thereby releasing the mount. (The time-delay mechanism is shown in Fig. 3.)

7. High-Altitude Hypsometer. This hypsometer is designed to provide resistance-output pressure information from 220,000 to 80,000 feet. It is a percolating type, with safrole used for the liquid. The boiling point temperature of the liquid, measured with a bead thermistor, is a

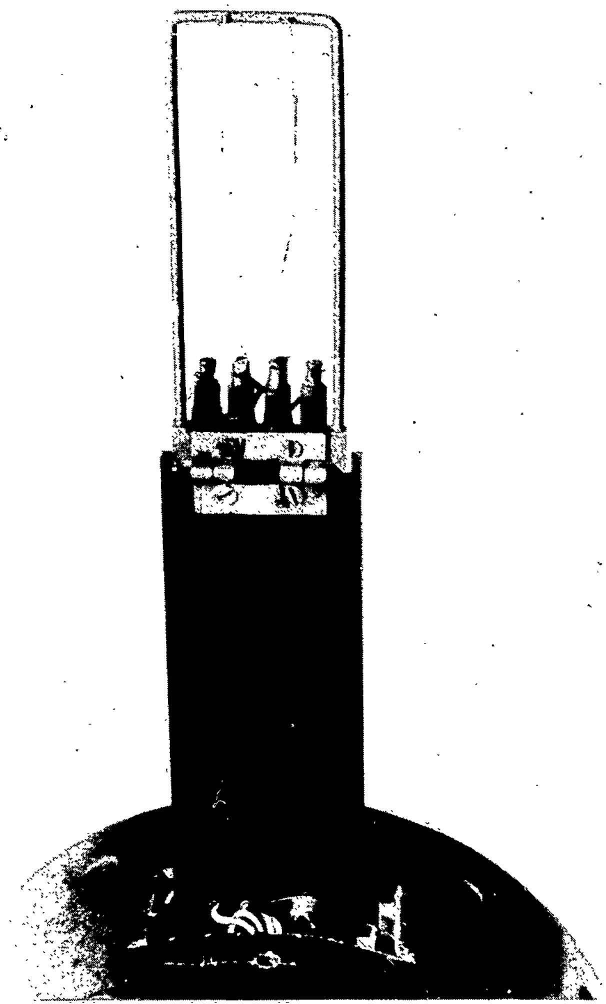


Fig. 2. Sensor Mount, with Thermistors Installed

function of pressure. A heater is included to provide pressure data down to the 80,000-foot level. The heater operates at 6V, 1.5 amperes. The hypsometer is designed so that the higher the altitude reached (to 220,000 feet), the faster the pressure-sensing device responds to the ambient pressure.

a. Rod Thermistor. This is an aluminum-coated ceramic-rod thermistor 10 mils in diameter by 3/8 inch in length, with a response time of four seconds at 200,000 feet from 33 to 66% of the temperature change. It was developed by Bendix-Friez on an Air Force contract.

b. Bead Thermistor. The bead thermistor is 10 mils in diameter with 1-mil wire leads, with a response time of less than one second at 200,000 feet and from 33 to 66% of the temperature change. Bead thermistors are normally glass-coated. Aluminum coating is deposited on the glass, and a layer of silicon monoxide is added.

ARCAS Rocket

The rocket is 4.3 inches in diameter by 61 inches long and consists of a motor case filled with solid end-burning-type propellent. Forward of the propellent is a 75-second timer which actuates an explosive charge. Included is a parachute compartment encasing a 15-foot-diameter hemispherical parachute with alternate reflective panels in order to provide a radar target. A plastic nose-cone and metal base-plate assembly house the instrument payload.

The rocket is launched from a closed-breech launcher, with an exit velocity of approximately 200 feet per second. It burns for 28 seconds, and reaches a maximum velocity of 3600 feet per second, burn-out occurring at 42,000 feet. At burn-out, the timer mechanism is actuated. Coasting for 75 seconds, the rocket and payload reach an altitude of 200,000 to 230,000 feet from sea-level launch. At apogee, or 128 seconds from ignition, the timer actuates an explosive mechanism which ejects the parachute, nose-cone, and payload from the spent rocket-motor case. The parachute deploys at 200,000 feet or above, with the nose-cone and instrumentation suspended.

The rocket-parachute assembly was developed by Atlantic Research Corporation on an Office of Naval Research contract.

Rawin Set AN/GMD-2

This set was developed by USAELRDL to track balloon-borne Radiosonde AN/AMQ-9. It automatically tracks balloon-borne radiosondes, recording range change, pressure, temperature, and humidity information. The rawin set consists of the following:

1. Pedestal. The pedestal consists of a 1660-mc to 1700-mc antenna and reflector, mixer, and a receiver equipped with AFC. An antenna-control system operates the azimuth and elevation tracking servo system; a signal comparator, which is used to generate the 81.94-kc subcarrier and receive the returned subcarrier through the receiver, thereafter converts phase shift to range change; and a 403-mc, 20-watt transmitter, 25% amplitude modulated with the 81.94-kc subcarrier, used to transmit the ranging signal, is located on the pedestal.

2. Control Recorder C-1406. Control Recorder C-1406, operating from driving motors and servos from the pedestal, automatically records azimuth and elevation angles to 0.01 degree, time of operation to 0.1 minute, range change in yards, and contains an altitude computer used in balloon-flight applications.

3. Radiosonde Recorder AN/TMQ-5. Radiosonde Recorder AN/TMQ-5 converts the pulse rate to a chart print-out; the maximum pulse rate input is 220 pps. It can be adapted for recording higher maximum pulse rates. It converts pulses received through the rawin receiver and control recorder to a dc output which positions a servo-driven pen. The chart is divided into 100 divisions. The chart drive speed is 1/2, 1, or 2 inches a minute, which can be selected.

The following changes were made in Rawin Set AN/GMD-2 for adaptation to rocket radiosonde tracking:

Radiosonde Recorder AN/TMQ-5 pen-drive gear is changed to permit total pen travel time from 0 to 100 divisions in less than one second. Modification kits made from drawings listed in SigC drawing ES-DL-191856 have been constructed, and this modification will be incorporated in the AN/TMQ-5.

A graphic recorder is connected to the output of the phase-comparing circuit in Control Recorder CM-63/GMD-2. A shorting switch is connected to the input circuit of the servo-drive amplifier in the signal comparator. Range-change is recorded on the graphic recorder during the rocket flight, with the shorting switch closed. After apogee is reached, range change is automatically recorded through the signal comparator control recorder system by disconnecting the graphic recorder from the comparator and by opening the shorting switch. Additional information is contained in reference 1.

FLIGHT-TEST RESULTS

Overall Results

Location: Santa Rosa Missile Test Facility, Eglin AFB, Florida.

Date: 14 to 18 June 1962.

Sensors used: Ten-mil-diameter bead thermistors, aluminum coated, Victory Engineering type TX-932.

Ten-mil-diameter by 3/8-inch-long aluminum-coated rod thermistors, Bendix-Friez part No. 114319-1.

Number of radiosondes tested: Five.

Rocket Performance. Satisfactory on all flights.

Parachute Performance. Satisfactory on 4 out of 5 flights.

Radiosonde Performance. Three satisfactory flights, with all data obtained. One radiosonde tracked to apogee, then to splash. All data

channels operated satisfactorily, but none recorded because of separation of nose cone from the parachute. One radiosonde was unsatisfactory; the transmission was interrupted long enough to lose the range-change sequence, and the thermistor mount did not extend after separation, thereby causing loss of temperature data. (See table 1.)

Location: Pacific Missile Range, Point Mugu, California.

Date: 10 to 15 August 1962.

Sensors used: Ten-mil-diameter bead thermistors, glass coated, Gulton Industries type 41CV5.

Ten-mil-diameter by 3/8-inch-long aluminum-coated rod thermistors, Bendix-Friez part No. 1141319-1.

High-altitude hypsometer, Bendix Research Laboratory, prototype models, Contract DA 36-039 SC-84992.

Number of radiosondes tested: Four.

Rocket Performance: Satisfactory on all flights.

Parachute Performance. Satisfactory on 2 out of 4 flights. Nose cone separation from parachute occurred on two flights.

Radiosonde Performance. Two satisfactory flights, with all data obtained. One radiosonde tracked to apogee, then to splash. All data channels operated satisfactorily, but none recorded because of separation of nose cone from parachute. No ranging data obtained on one flight because of harmonic interference from 400-mc transmitter. All other data channels operated satisfactorily, but none recorded because of separation of nose cone from parachute. (See table 1.)

Temperature-Data Analysis, Pressure Data

Temperature-measuring thermistors were installed on a 5-inch mount, as illustrated in Figs. 1 and 2. Exposure of the sensors occurs 10 seconds after separation of the instrumented nose cone and parachute from the rocket motor case at apogee. A nose cone is permanently attached to the radiosonde during parachute descent. A time-delay mechanism (Fig. 3) is used to delay exposure of the sensors to the atmosphere for 10 seconds after separation. This is to prevent breakage of the sensors which could be caused either by the separation blast or by fouling of the parachute line before deployment of the parachute.

Up to four sensors may be installed, either within the radiosonde or on the sensor mount. A motor-commutator combination provides time-sharing of four channels of information with a dwell time of 5 seconds on each sensor and repeats cycling every 30 seconds. A reference channel is included on a fifth commutator segment. A transistor blocking oscillator is used to convert sensor resistance to pulse repetition frequency; the resistance

TABLE I. COMMENTS ON RADIOSONDE PERFORMANCE

RADIOSONDE SER NO (AN/DMQ-6)	TEST NO PLACE DATE TIME OF LAUNCH	RANGING AGREEMENT WITH RADAR DURING ROCKET ASCENT	READABILITY OF RANGE CHANGE RECORDING DUR. ROCKET ASCENT	RANGING AGREEMENT WITH RADAR DURING PARACHUTE DESCENT	TYPE GMD-2 USED IN TRACKING	QUALITY OF TELEMETRY DURING PARACHUTE DESCENT	82KC RETURN OUT OF J1002 OF RAWIN RECEIVER PEAK TO PEAK	PULSE RETURN OUT OF J1002 OF RAWIN RECEIVER AXIS TO PEAK	RANGING RECEIVER MAXIMUM SENSITIVITY MICROVOLTS	RADIOSONDE TRANSMITTER FREQUENCY MC
162	AS-J-15-6 EGLIN FLA 15 JUNE 62 1415 CST	GOOD	GOOD	MAX. DEVIATION 1000 FT DOWN TO 83000 FT.	PRODUCTION	GOOD FROM 213000 FT DOWN	.4	.5	70	1683
135	AS-J14-2 EGLIN FLA 14 JUNE 62 1445 CST	GOOD	GOOD	NOSE CONE SEPARATED FROM PARACHUTE	PRODUCTION	NO DATA DUE TO RAPID DESCENT	.12	.2	70	1687
116	AS-J14-4 EGLIN FLA 14 JUNE 62 1658 CST	TIME LAG, APPEARS GOOD	GOOD	CROSSOVER AT 164000FT ABOUT 2000 FT DIFFERENCE AT MAX & MIN ALT.	PRODUCTION	INTERRUPTED DOWN TO 150000 FT, GOOD THEREAFTER	.2	.3	100	1688
161	AS-J18-8 EGLIN FLA 18 JUNE 62 1242 CST	NOT AVAILABLE GROUND RECORDER INOPERATIVE	NOT AVAILABLE	LOCKED IN WITH RADAR AT 192416 FT, AGREEMENT BETWEEN 211000 FT AND 110000 FT.	PRODUCTION	GOOD FROM 211000 FT	.6	.6	100	1685
152	AS-J25-11 EGLIN FLA 25 JUNE 62 1450 CST	GOOD	GOOD	NOT GOOD, BOTH GMD-2 AND RADAR BELIEVED IN ERROR, TOO RAPID DESCENT RATE WITH BOTH SYSTEMS	PRODUCTION	DATA INTERRUPTED OR MISSING UNTIL TT6 MIN. GROUND INTERFERENCE SUSPECTED	.2	.4	150	1685
157	226011A PMR CALIF. 14 AUG 62	NO RADAR DATA TO T + 1.0 MIN, TIME LAG APPARENT	GOOD	NOSE CONE SEPARATED FROM PARACHUTE	XE-4 TYPE	NO DATA DUE TO RAPID DESCENT	.2	.3	60	
163	226011B PMR CALIF. 14 AUG 62 0940 PDT	NO RADAR DATA	GOOD	AGREEMENT TO 1000 FT OR BETTER	XE-4 TYPE	GOOD FROM 155000 FT	.15	.4	60	1686
142	222005 PMR CALIF. 0900 PDT	GOOD	GOOD	AGREEMENT TO 1500 FT OR BETTER TO 84000FT.	XE-4 TYPE	GOOD FROM 185000 FT	.5	.3	75	1686
153	001A PMR CALIF. 17 AUG. 62	NOT AVAILABLE INTERFERENCE BETWEEN 403 MC XMTR AND 1680 MC RECVR	NOT AVAILABLE	NOSE CONE SEPARATED FROM PARACHUTE	XE-4 TYPE	NO DATA DUE TO RAPID DESCENT	.4	.5	250	1682

Fig. 3. Time-Delay Mechanism

range is 1 megohm to 1000 ohms, with a pulse rate of 10 to 200 pps. The most accurate range of operation is between 300,000 and 10,000 ohms, where better than 1% readability of resistance is obtained through the telemetry system. The blocking oscillator, operating from a 1.35V battery, was designed particularly for use with the microbead thermistor. A maximum of 5 microwatts is dissipated through the thermistor during a measurement. This causes self-heating of the thermistor of less than 1°C at an altitude of 200,000 feet, and less than this value at lower altitudes.

The accuracy of the telemetry system was checked in flight on these and other tests previously performed. This was done by installing a fixed temperature-stable 70,000-ohm resistor (approximately midrange) as one of the sensors. The reduced data indicated a resistance within 0.5% of the actual value throughout the flight.

The temperature data are shown in Figs. 4, 5, 6, 7, and 8. Temperature comparison data are tabulated in table 2. Thus, a direct comparison can be made between sensors, and an observation can be made of the day-to-day variation in the temperature at a specific altitude. The altitude data are probably within 125 feet of the true altitude. This figure is based on altitude differences obtained between two radars tracking the same target.

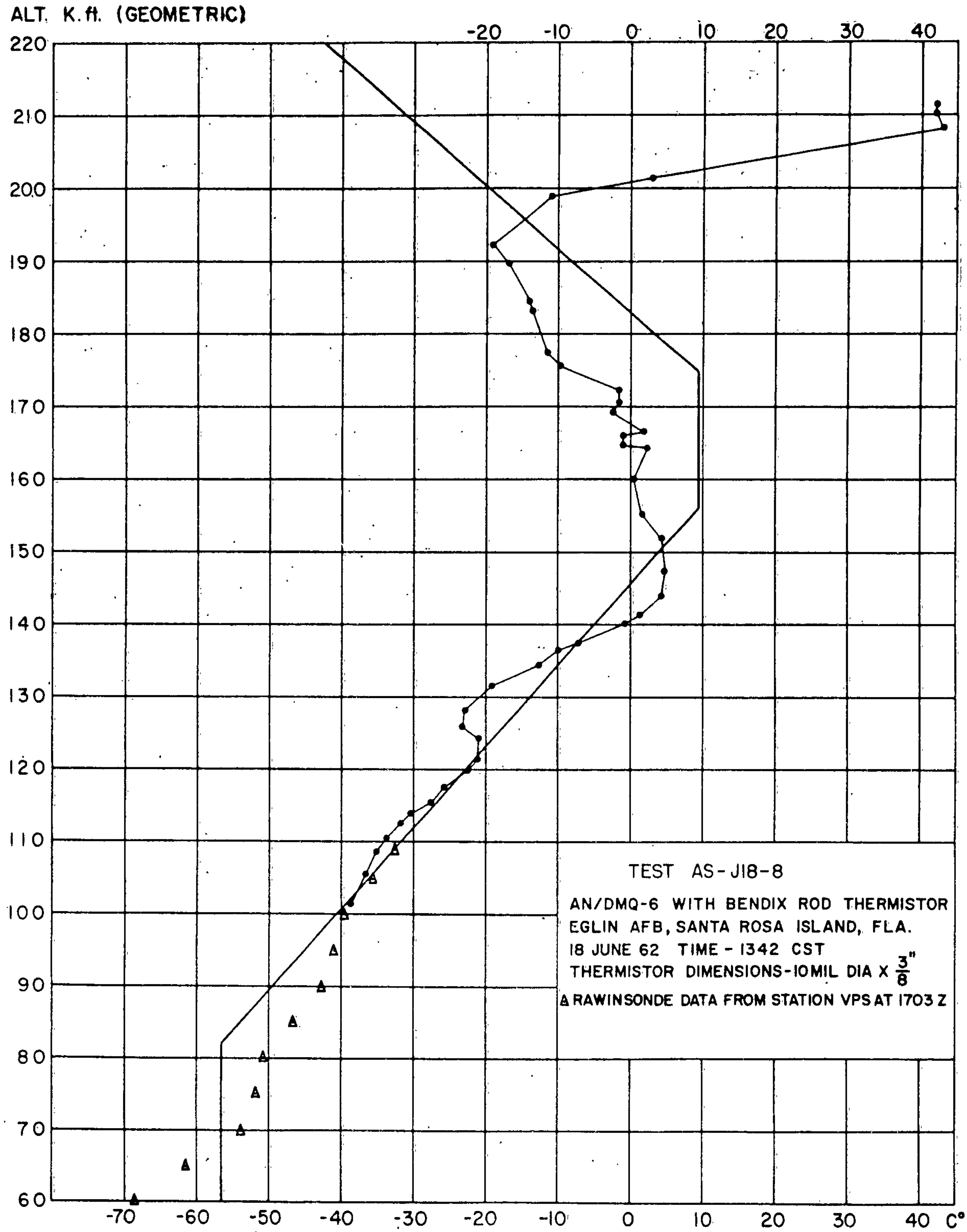
The following are some observations and/or conclusions derived from the data:

1. Temperature Measurements. The temperature measured to 170,000 feet is accurate to about 2°C, based on the agreement obtained with two different types of sensors. At 175,000 feet and above, the only reasonable data were obtained with the aluminum-coated rod thermistor used in test AS-J18-8. Because of insufficient data, no estimate of the accuracy of the temperature measurements above 175,000 feet can be given at this time.

2. Response Time. Laboratory measurements indicate that the response time (30 to 70%) of the bead thermistor is 1 second at a pressure equivalent to 200,000 feet. The response time of the rod thermistor was measured at 4 seconds. From the results of tests, shown in Figs. 4, 5, and 6, it appears that the difference in response time is not detrimental to the performance of the rod thermistor as a temperature sensor to 192,000 feet in this system.

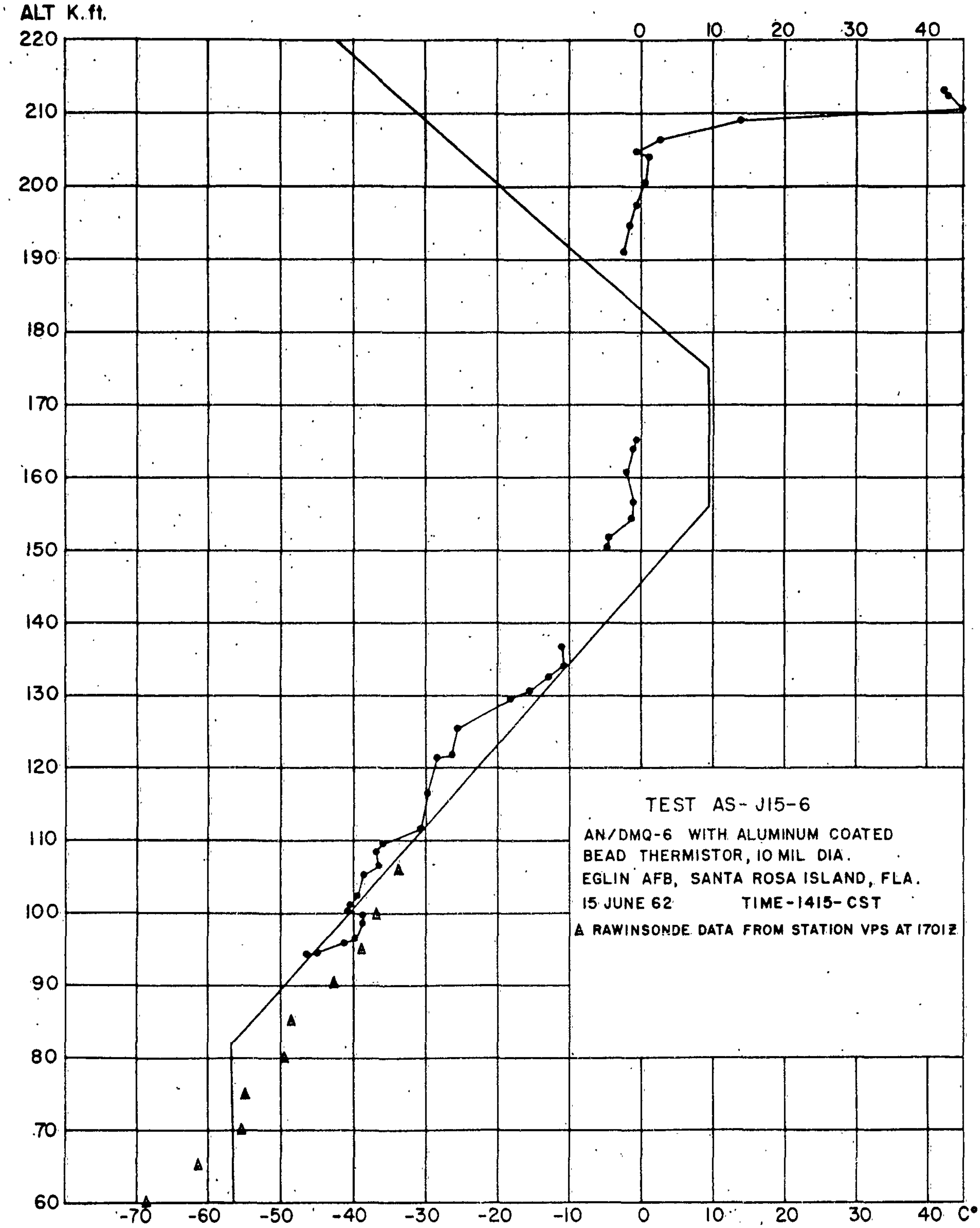
It appears from the results shown in Fig. 5 that the bead thermistor lacks the capability of providing true atmospheric temperature at altitudes above 170,000 feet at the prevailing parachute-drop rates. This conclusion is based not only on the results of these tests, but from observation of data recorded in several other rocket flights.

The aluminum coating applied on the bead thermistor does not have any significant effect when compared with temperature results obtained with the glass-coated bead (see Figs. 6 and 7). It should be pointed out, however, that in storage a certain amount of oxidation occurred to the aluminum coating. When viewed through a microscope, it was seen that up to one-third of the surface was black. Theoretically, oxidation would radically increase



ALT. K.ft. (GEOMETRIC)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
-20
-10
0
10
20
30
40
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40 C°
TEST AS-J18-8
AN/DMQ-6 WITH BENDIX ROD THERMISTOR
EGLIN AFB, SANTA ROSA ISLAND, FLA.
18 JUNE 62 TIME - 1342 CST
THERMISTOR DIMENSIONS-10MIL DIA X 3/8"
Δ RAWINSONDE DATA FROM STATION VPS AT 1703 Z

Fig. 4



ALT K.ft.
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
0 10 20 30 40
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 C°
TEST AS-J15-6
AN/DMQ-6 WITH ALUMINUM COATED
BEAD THERMISTOR, 10 MIL DIA.
EGLIN AFB, SANTA ROSA ISLAND, FLA.
15 JUNE 62 TIME-1415-CST
▲ RAWINSONDE DATA FROM STATION VPS AT 1701Z

Fig. 5

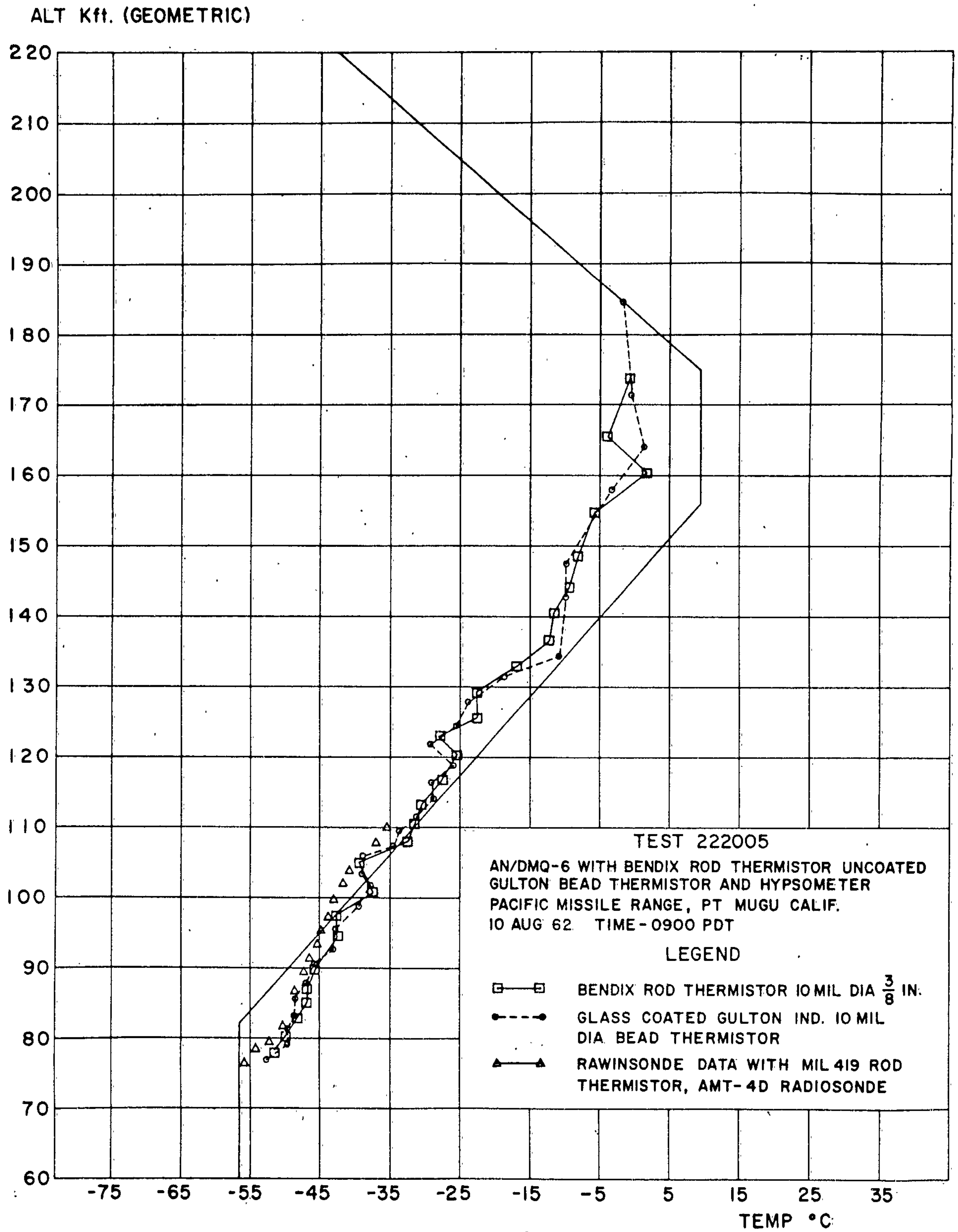
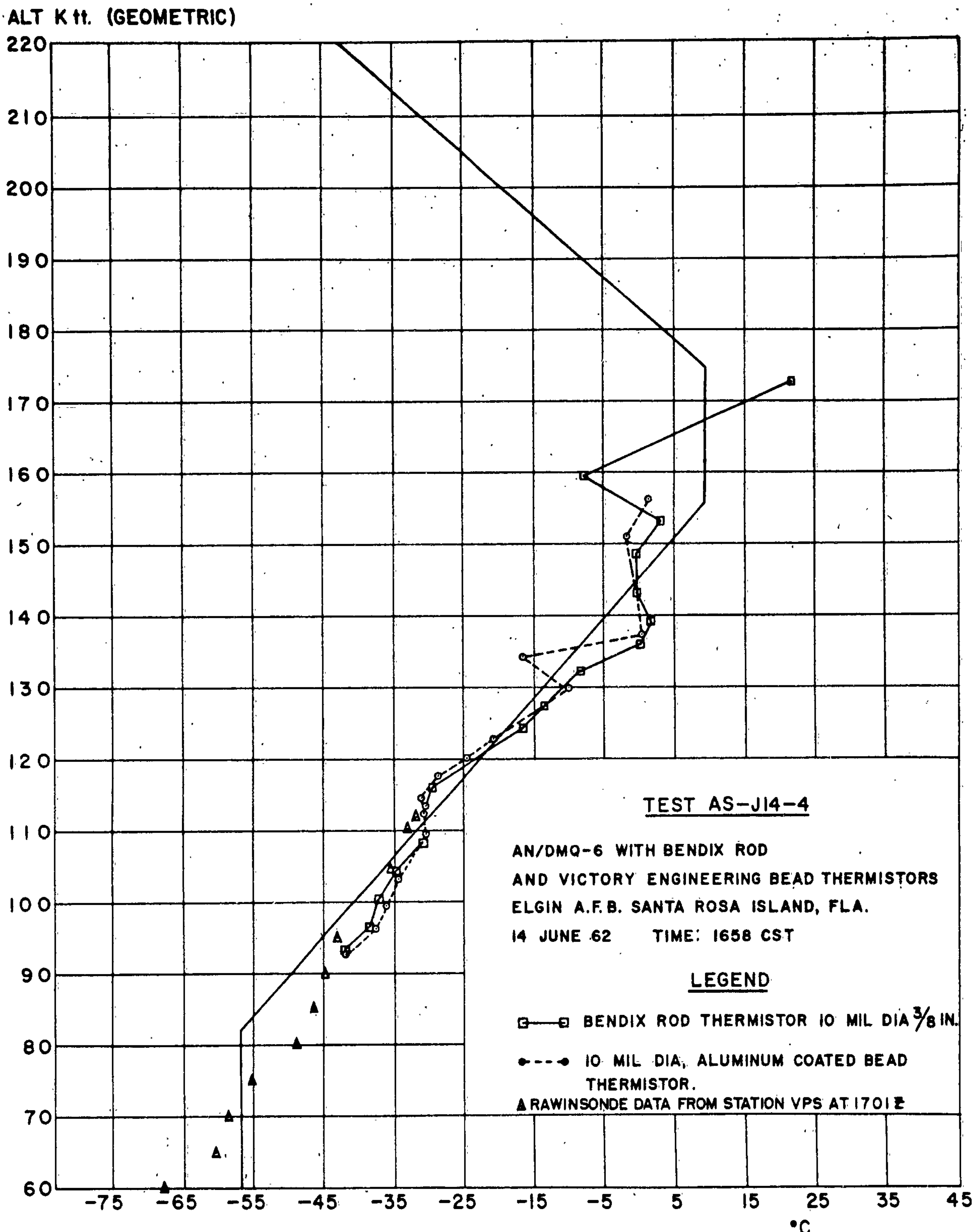

ALT Kft. (GEOMETRIC)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
-75
-65
-55
-45
-35
-25
-15
-5
5
15
25
35
TEMP °C
TEST 222005
AN/DMQ-6 WITH BENDIX ROD THERMISTOR UNCOATED
GULTON BEAD THERMISTOR AND HYPSOMETER
PACIFIC MISSILE RANGE, PT MUGU CALIF.
10 AUG 62 TIME-0900 PDT
LEGEND
BENDIX ROD THERMISTOR 10 MIL DIA 3/8 IN.
GLASS COATED GULTON IND. 10 MIL DIA BEAD THERMISTOR
RAWINSONDE DATA WITH MIL 419 ROD THERMISTOR, AMT-4D RADIOSONDE

Fig. 6



ALT K ft. (GEOMETRIC)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
-75
-65
-55
-45
-35
-25
-15
-5
5
15
25
35
45
°C
TEST AS-J14-4
AN/DMQ-6 WITH BENDIX ROD
AND VICTORY ENGINEERING BEAD THERMISTORS
ELGIN A.F.B. SANTA ROSA ISLAND, FLA.
14 JUNE 62 TIME: 1658 CST
LEGEND
BENDIX ROD THERMISTOR 10 MIL DIA 3/8 IN.
10 MIL DIA, ALUMINUM COATED BEAD THERMISTOR.
RAWINSONDE DATA FROM STATION VPS AT 1701 Z

Fig. 7

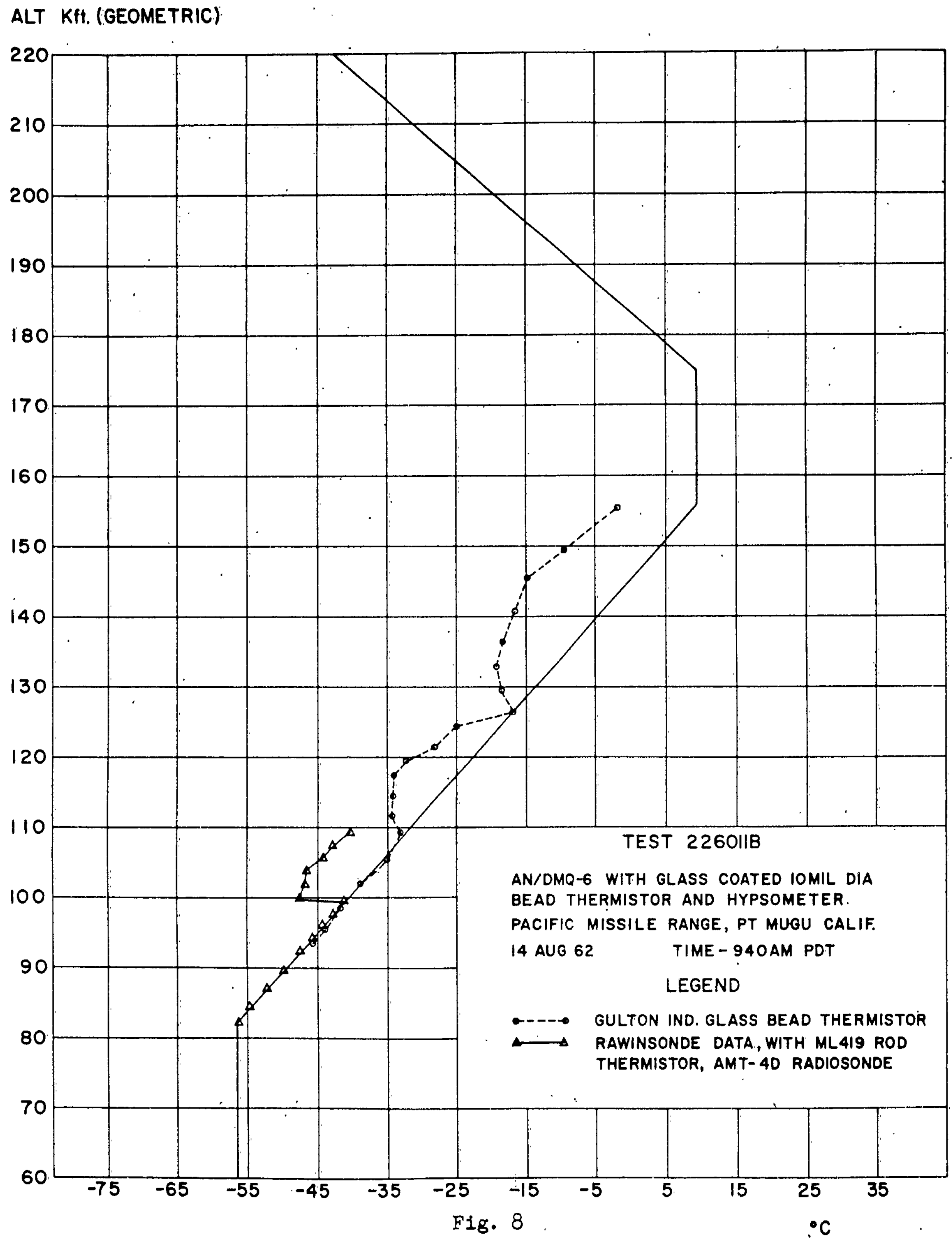

ALT Kft. (GEOMETRIC)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
-75
-65
-55
-45
-35
-25
-15
-5
5
15
25
35
°C
TEST 226011B
AN/DMQ-6 WITH GLASS COATED 10MIL DIA BEAD THERMISTOR AND HYPSOMETER.
PACIFIC MISSILE RANGE, PT MUGU CALIF.
14 AUG 62 TIME - 940AM PDT
LEGEND
GULTON IND. GLASS BEAD THERMISTOR
RAWINSONDE DATA, WITH ML419 ROD THERMISTOR, AMT-4D RADIOSONDE

Fig. 8

TABLE II. ALTITUDE-TEMP DATA, COMPOSITE FOR ALL FLIGHTS, TEMP IN °C

ALTITUDE		EGLIN FLA.				PMR CALIFORNIA			
FT x 1000	KM	TEST AS-J18-8 18 JUNE 62 1342 EST ALUM CTD ROD THERMISTOR	TEST AS-J15-6 15 JUNE 62 1415 EST ALUM CTD BEAD THERMISTOR	TEST AS-J14-4 14 JUNE 62 1658 CST ALUM CTD ROD	ALUMINUM CTD BEAD	TEST 222005 10 AUG 62 0900 PDT ALUM CTD ROD	GLASS CTD BEAD	TEST 226011B 14 AUG 62 940 AM PDT GLASS COATED BEAD	1958 ICAO STD TEMP
210	64	+42 (IN NOSECONE)	+45 (IN NOSECONE)						-31
205	62.5	+23.5	-1						-25
200	61	-5	0						-19
195	59.4	-16	-1						-14
192.5	58.7	-19	-2						-11
190	57.9	-17							-8
185	56.4	-14					-2		-2
180	54.9	-12					-1		+4
175	53.3	-8				-1	-1		+10
170	51.8	-1		+15		-2	0		+10
165	50.3	-1	-1	+4		-4	+1		+10
160	48.8	+1	-2	-8		+2	-2		+10
155	47.2	+2	-1	0	0	-5	-5	-2	+8
150	45.7	+5	-5	0	-1	-8	-8	-9	+4
145	44.2	+5		0	0	-9	-10	-15	0
140	42.7	-1		+1	0	-11	-10	-17	-5
130	39.6	-21	-17	-10	-10	-21	-21	-18	-14
120	36.6	-25	-29	-24	-24	-26	-26	-22	-23
110	33.5	-39	-35	-30	-30	-32	-32	-33	-31
100	30.5	-40	-40	-37	-36	-39	-39	-41	-40
90	27.4					-46	-46		-49
80	24.4					-50	-50		-56

the absorptivity over a perfectly aluminized body, causing an additional rise in temperature within the thermistor.

The results of these data indicate that the mean summer daytime temperatures in the 155,000- to 175,000-foot level, at the latitude in which the data were obtained, are 10 degrees colder than those given in the 1958 ICAO atmospheric tables. There is a probability that temperatures above 175,000 feet are also colder.

Occasionally, heat "spikes" up to 8°C are recorded during a 5-second temperature trace when the bead thermistor is commutated into the circuit. The base of the spike, if it is recorded, is used as the proper temperature reading. If a base does not appear, the data are not used. The cause of these temperature excursions is not known, but they have been observed occasionally on specially modified balloon radiosondes, and always above the tropopause.

A percolator-type hypsometer, housed within the radiosonde, was included as a sensor at the Pacific Missile Range. The pressure data obtained are shown in Figs. 9 and 10. (A complete analysis of the high-altitude hypsometer will be treated in a separate report.) Figure 11 illustrates the installation of the hypsometer. Although not indicated in this figure, pressure measurements are obtained with the nose cone attached during parachute descent. The temperature was measured inside the nose cone during a radiosonde flight with a thermistor located near the sensor mount at the base of the instrument. A temperature of +37°C was obtained at 200,000 feet, with a gradual increase to +53°C by the time the parachute and nose cone had fallen to 100,000 feet.

Wind Data

Wind data were determined by subtracting the N-S and E-W components of travel over a 2500-foot altitude segment, and dividing the difference by the appropriate time interval. No data were used until 3 minutes after launch; this time lapse prevents the inclusion as data of the forward motion imparted by the rocket trajectory. Deployment of the parachute started 2.1 minutes after launch. At the Eglin AFB site, trajectory was aimed toward the south, imparting an apparent northerly wind component to the parachute and payload. At the Pacific Range, firings were directed toward the west, imparting an easterly component. All flights indicated prevailing east winds with relatively small north or south components, at least down to a level of 80,000 feet.

Wind data are illustrated in Figs. 12, 13, 14, and 15. Included in these data are rawinsonde winds, derived from ROBIN (falling-sphere) experiments performed within hours of the radiosonde tests, and also from a parachute without a payload. Wind components from the ROBIN flights were derived in the same manner as those of the parachute and payload. Data from an AN/FPS-16 radar were used throughout.

The ROBIN falling sphere is a superpressure balloon containing a corner reflector as a radar target. Carried aloft in excess of 200,000 feet with

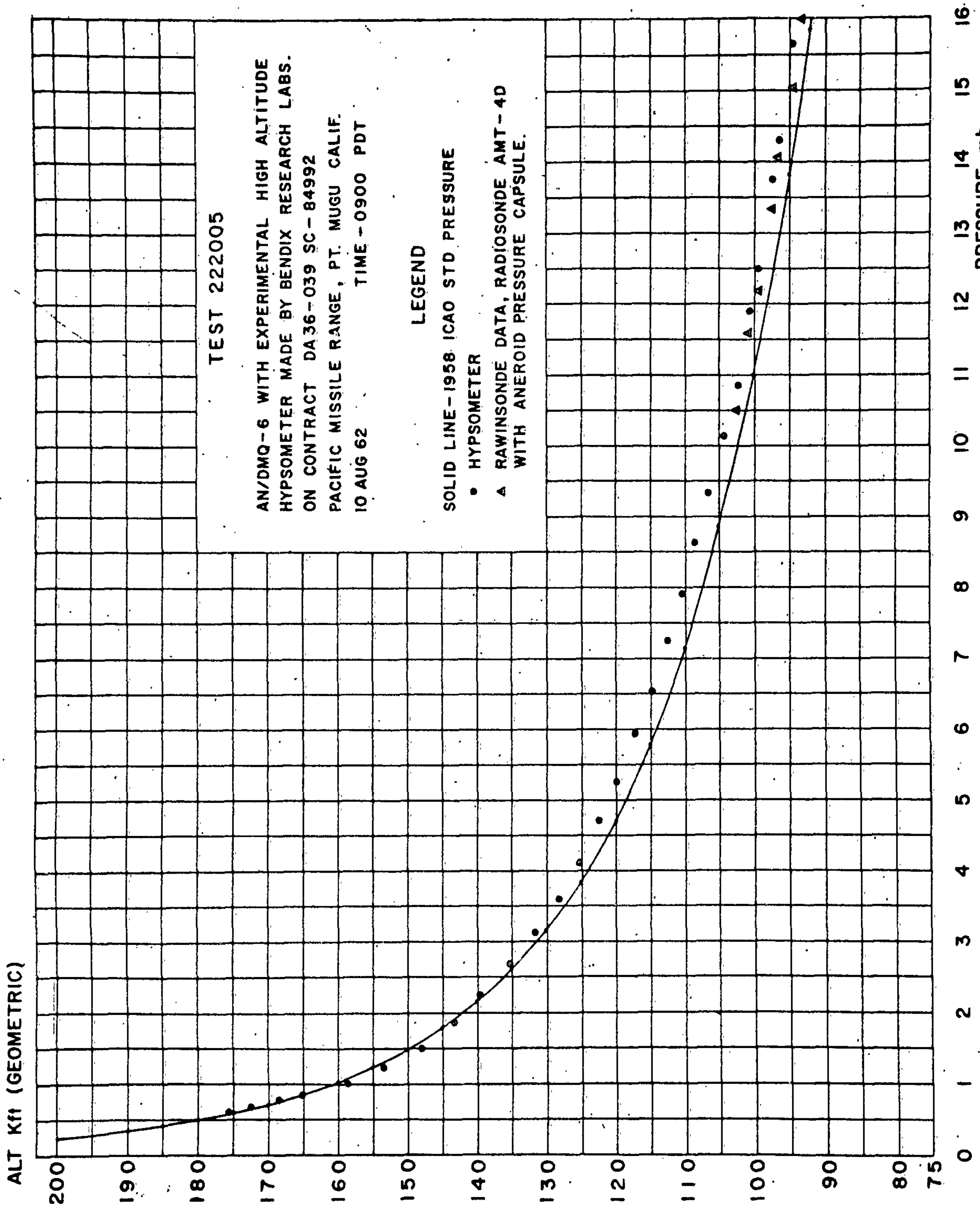
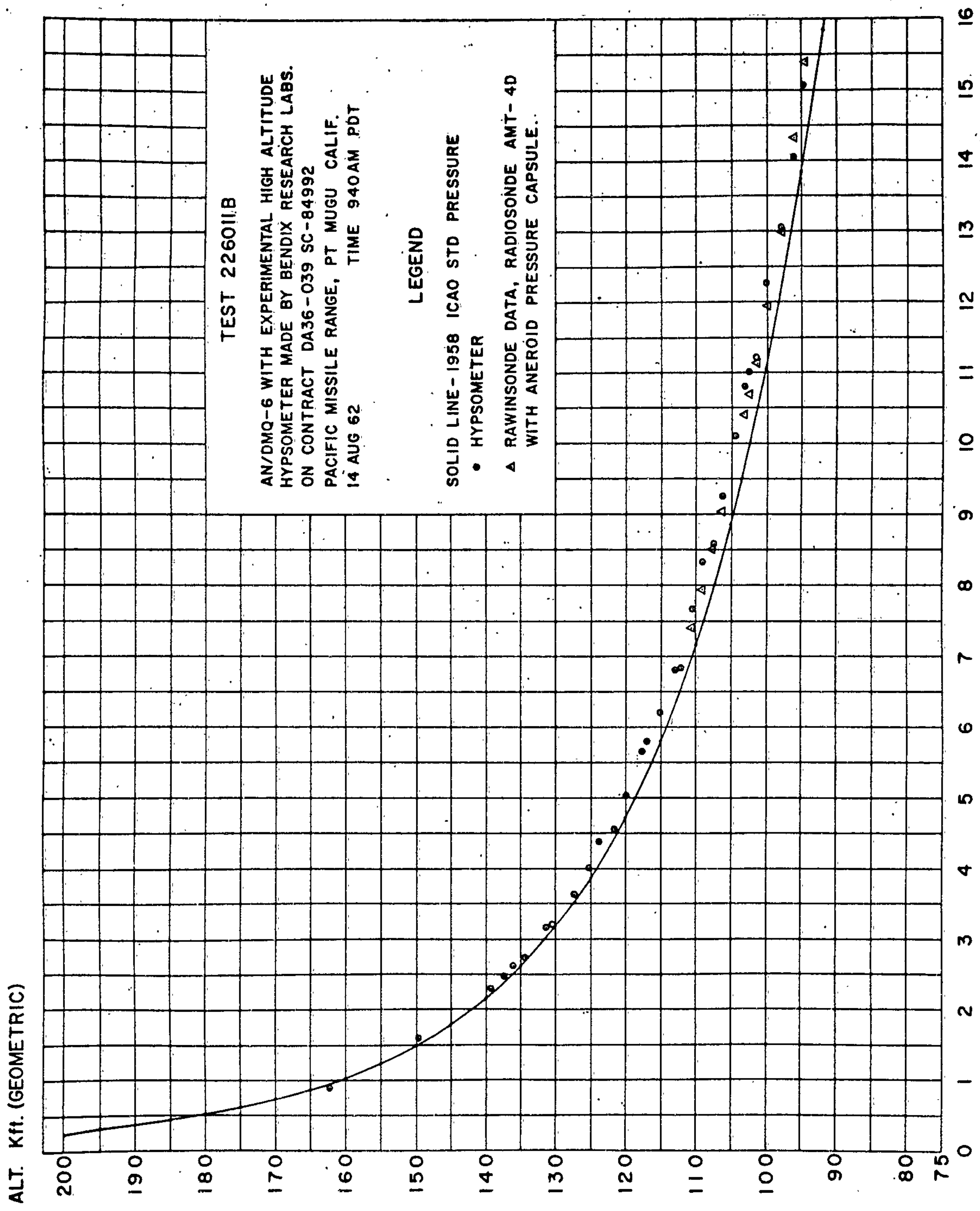

TEST 222005
AN/DMQ-6 WITH EXPERIMENTAL HIGH ALTITUDE
HYPSOMETER MADE BY BENDIX RESEARCH LABS.
ON CONTRACT DA36-039 SC-84992
PACIFIC MISSILE RANGE, PT. MUGU CALIF.
10 AUG 62 TIME-0900 PDT
LEGEND
SOLID LINE-1958 ICAO STD PRESSURE
● HYPSOMETER
▲ RAWINSONDE DATA, RADIOSONDE AMT-4D WITH ANEROID PRESSURE CAPSULE.
ALT Kft (GEOMETRIC)
200
190
180
170
160
150
140
130
120
110
100
90
80
75
PRESSURE mb
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Fig. 9



TEST 226011.B
AN/DMQ-6 WITH EXPERIMENTAL HIGH ALTITUDE HYPSOMETER MADE BY BENDIX RESEARCH LABS. ON CONTRACT DA36-039 SC-84992
PACIFIC MISSILE RANGE, PT MUGU CALIF.
14 AUG 62 TIME 940 AM PDT
LEGEND
SOLID LINE-1958 ICAO STD PRESSURE
• HYPSOMETER
Δ RAWINSONDE DATA, RADIOSONDE AMT-4D WITH ANEROID PRESSURE CAPSULE.
ALT. Kft. (GEOMETRIC)
200
190
180
170
160
150
140
130
120
110
100
90
80
75
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PRESSURE mb

Fig. 10

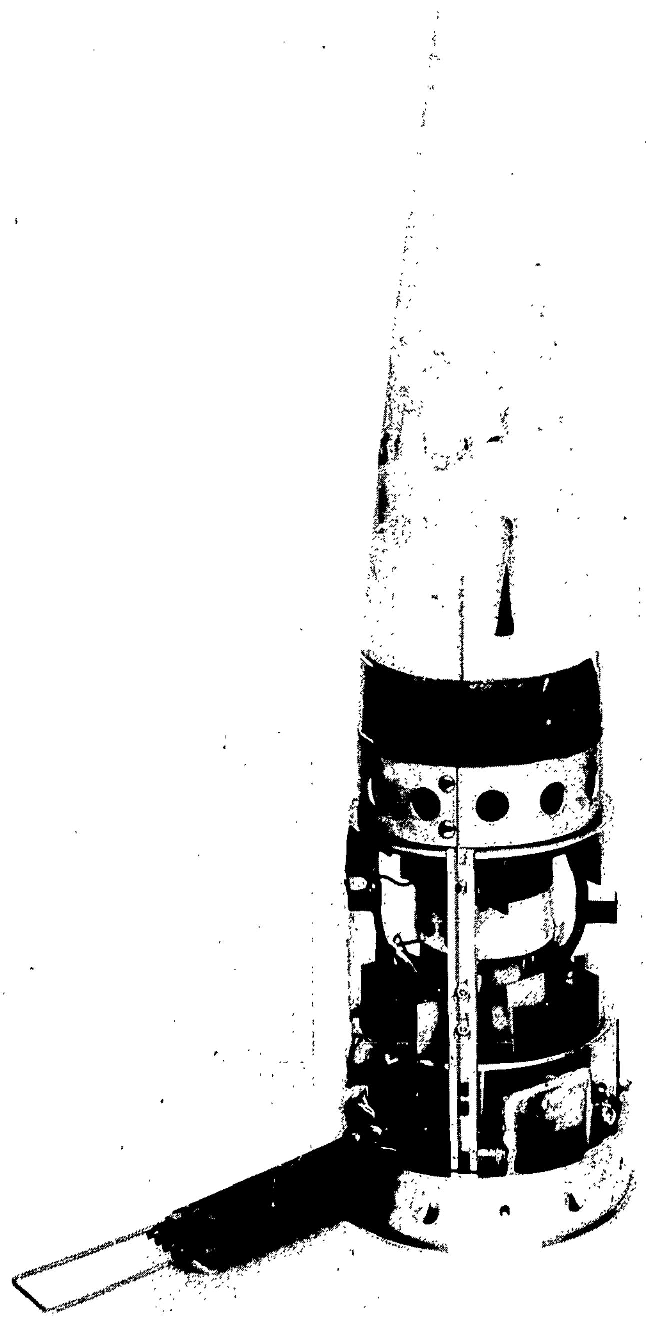


Fig. 11

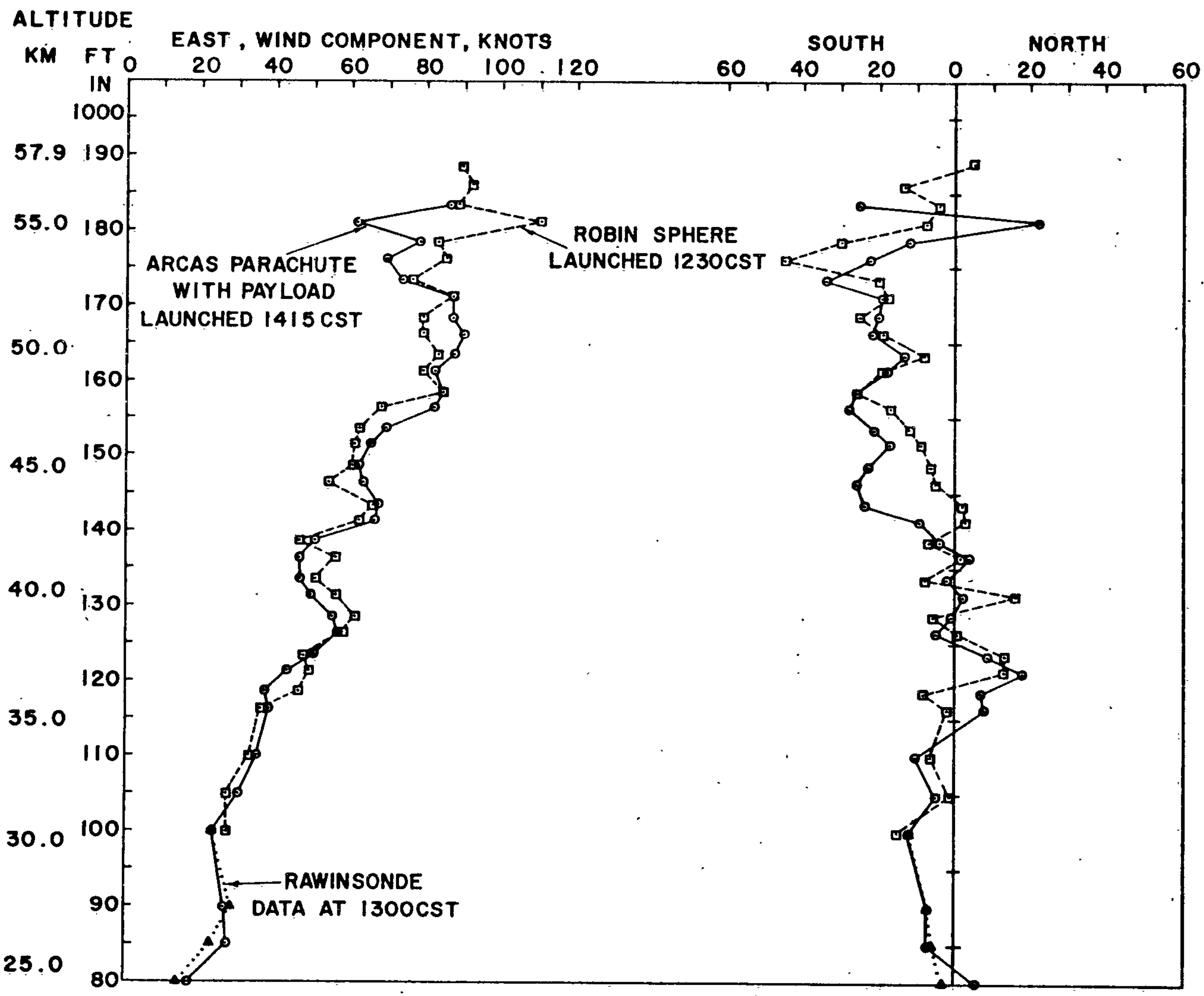
SIGRA/SL-62-411 FORT MONMOUTH, N. J.

ROCKET RADIOSONDE AN/DMQ-6 . (EXPERIMENTAL)

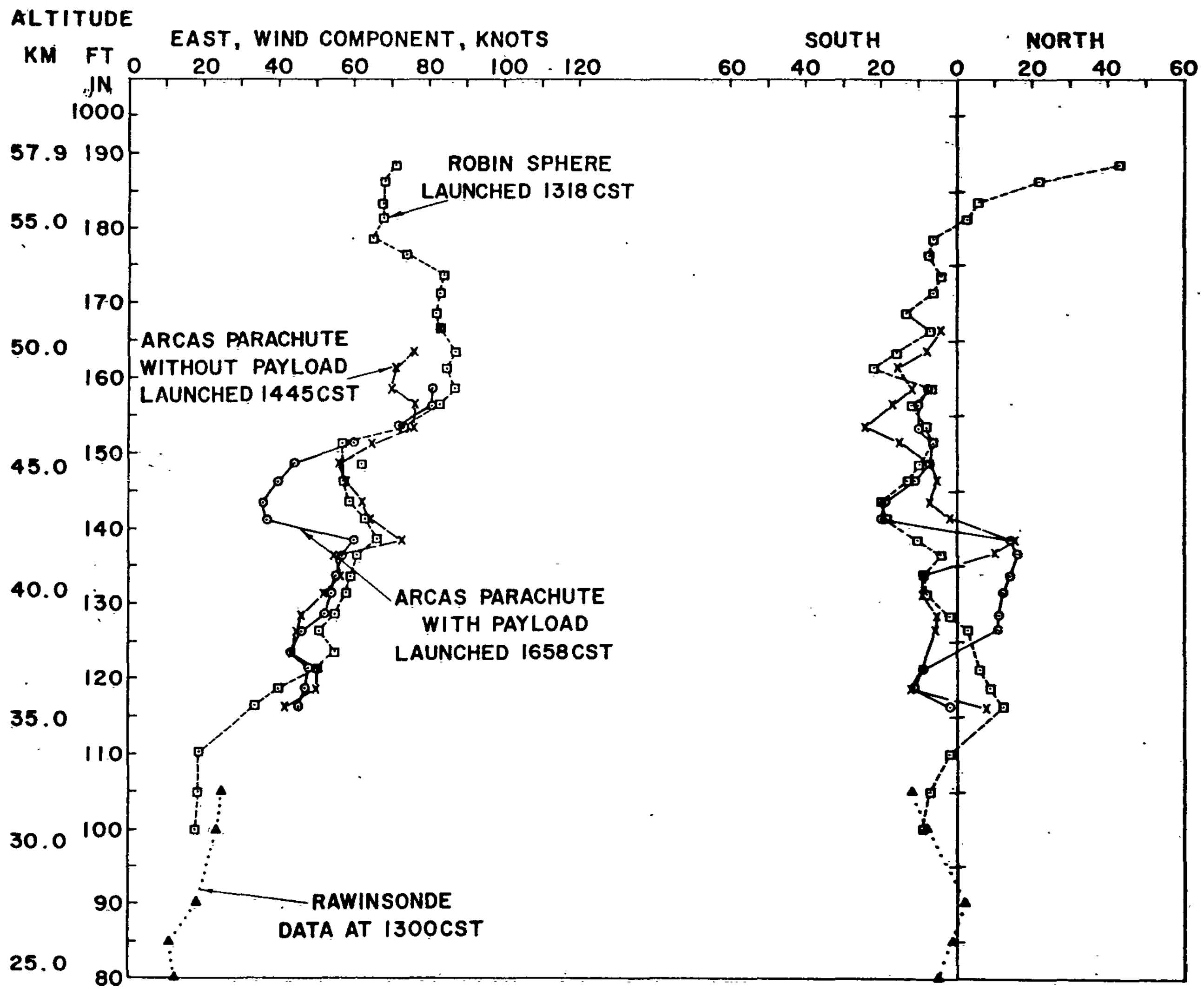
FRONT VIEW . SHOWING HYPSOMETER INSTALLATION

5 MAR 62 FIG. 5

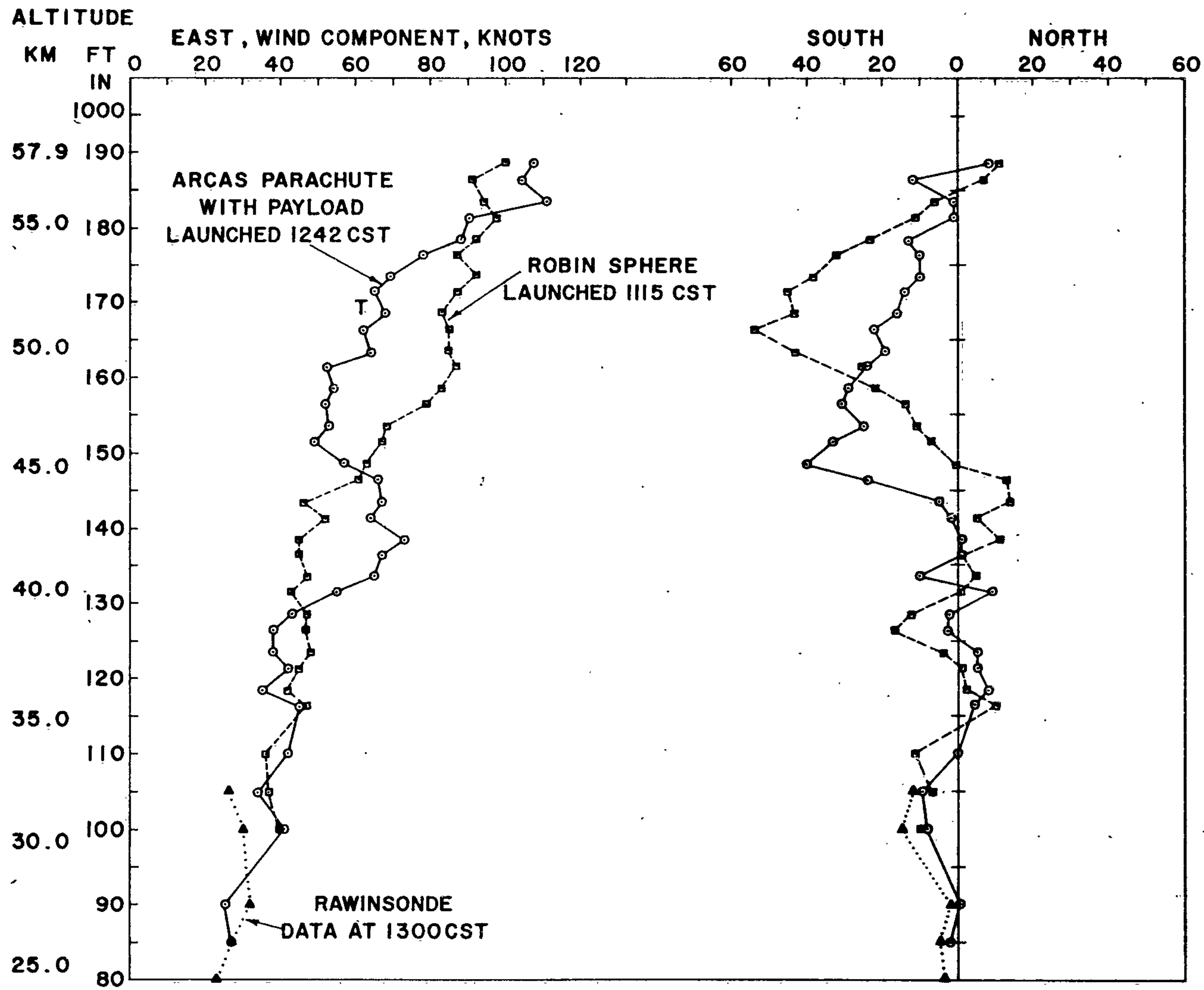
U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY



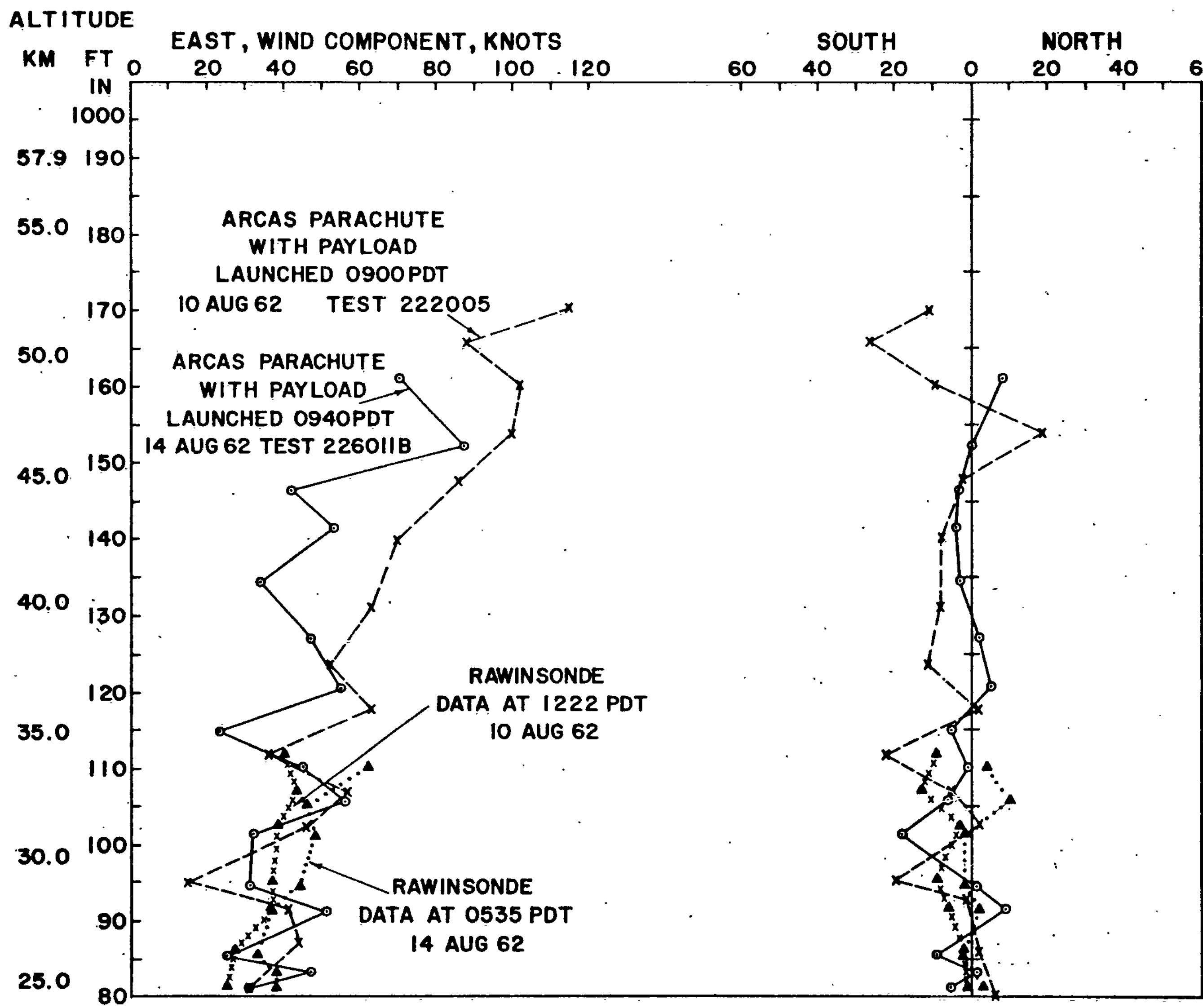
ARCAS PARACHUTE WITH 7.25LB PAYLOAD, TEST AS-J15-6
ROBIN SPHERE, TEST AWS-6-2
FIG.12. WIND DATA, EGLIN AFB FLA., 15 JUNE 1962



ARCAS PARACHUTE WITH 7.25LB PAYLOAD, TEST AS-J14-4
ARCAS PARACHUTE WITHOUT PAYLOAD, TEST AS-J14-2
ROBIN SPHERE, TEST AWS-4-2
FIG.13 WIND DATA, EGLIN AFB FLA., 14 JUNE 1962



ARCAS PARACHUTE WITH 7.25LB PAYLOAD, TEST AS-J18-8
ROBIN SPHERE, TEST AWS-9-2
FIG. 14. WIND DATA, EGLIN AFB FLA., 18 JUNE 1962



ARCAS PARACHUTE WITH 8.25LB PAYLOAD, TEST 222005 AND 226011B
FIG. 15. WIND DATA, PMR CAL., 10 AND 14 AUG 1962

the ARCAS rocket, it is inflated at apogee and allowed to fall freely. It was developed by the U. S. Air Force Cambridge Research Laboratories to provide wind and density information.

Included in the wind data are those obtained with a parachute without a payload.

For comparison purposes, the following are the physical characteristics of the objects tracked:

Parachute - ARCAS	Balloon - ROBIN
Diameter, 15 ft.	Diameter, 3.28 ft.
Shape, hemisphere	Shape, sphere
Weight (without payload), 2.5 lbs.	Weight, 0.253 lb.
Weight of payload, 7.25 lbs.	

Since no simultaneously obtained flight data are available, a definite conclusion cannot be drawn as to the wind trackability of the parachute and nose-cone combination. It appears reasonable to assume, however, that winds measured are valid to at least 190,000 feet, providing the trajectory motion of the rocket is not included in the data reduction.

The descent rate of the parachute-payload assembly, as measured on three flights, is given in table III. These rates were determined from 10-second altitude differences.

Additional information on the falling-sphere experiments is contained in reference No. 2.

Rawin Set AN/GMD-2 Tracking Accuracy, through Parachute Descent

Altitude data obtained with the AN/DMQ-6 - AN/GMD-2 system were compared with those obtained with Radar Set AN/FPS-16. It is believed that the radar data in most instances are accurate to about 125 feet. A possibility of radar error exists at peak of trajectory when the parachute and nose-cone combination separates from the rocket motor case. This is when the radar operator must shift his target from the motor case to the radar-reflective parachute from which the instrumented nose cone is suspended. Altitude data were used as the comparison, since they are the end item desired for use with the telemetry data. These data would include both ranging and elevation-angle error.

At the Eglin AFB site, the rawin set was not oriented to an elevated target, but was carefully leveled with respect to the horizontal. The azimuth-angle orientation was obtained from previously surveyed points. At the Pacific Range site, both azimuth and elevation were oriented to a known position.

Range-change information is not recorded by the usual method during the entire flight. During the rocket portion, range change is recorded on a graphic recorder rather than on the AN/GMD-2 automatic recording system because of the high speed of the rocket motor. At apogee, when the

Table III. Descent Rate, in Feet per Second, of ARCAS Parachute with 7.25 Pounds Suspended

Altitude (feet times 1000)	AS-J15-6	AS-J18-8	AS-J14-4
210	389	269	
200	479	465	422
190	400	394	397
180	331	325	331
170	277	266	276
160	229	242	235
150	187	194	197
140	161	161	158
130	123	125	124
120	104	103	98
110	86	79	78
100	60	62	63
90	54	50	46
80	37	35	

Note: AN/FPS-16 altitude-differences over a ten-second period used to determine descent rates.

radiosonde distance is changing at a rate compatible with the AN/GMD-2 range-recording device, switch-over to this system is made in accordance with the procedure described in USASRDL Technical Report 2171.[1] This report does not mention the necessity of obtaining a manual print-out of the elevation angle at the moment of switch-over, which is required in order to obtain the exact moment when change-over occurred, for easier data-reduction. At the Eglin site, switch-over was made at T + 2 minutes, or near the time of separation of the payload but before peak trajectory. At the Pacific Range, switch-over was made at T + 3 minutes in order to observe the quality of the graphic recording beyond peak trajectory. The advantages to waiting for three minutes are a clearer range-change record and greater certainty of the accuracy of the data automatically recorded thereafter.

Table IV illustrates the comparison between AN/GMD-2 and AN/FPS-16 radar data. Each set of data was independently derived except that for test AS-J-18-8, where a lock-in was necessary because of a faulty galvanometer in the graphic recorder used to record range during the rocket flight. However, the range-return signal observed through the AN/GMD-2 comparator indicator appeared adequate for this flight. Except for test AS-J25-11, good agreement was obtained at apogee. The discrepancy in this particular test is attributed to radar difficulties as well as temporary loss of radiosonde signal just before separation between nose cone and rocket motor. Radar data indicate a continued ascent well after separation, then an unusually high fall rate thereafter. No definite conclusion could be drawn regarding this comparison.

Another discrepancy exists in the altitude data. Test AS-J14-4 shows that agreement with radar was obtained to T + 2.1 minutes, but thereafter a lower altitude was registered with AN/GMD-2 data to T + 4.5 minutes. From then on, a consistently higher altitude is indicated. This may have been due to a fault occurring in the radiosonde ranging receiver after separation, or possibly in the signal comparator external connections to the graphic recorder. On the other flights some difference in altitude may be attributed to a difference in time recorded at and after launch between the two tracking systems being compared. In some cases, because of difficulties in the control recorder print-out mechanism, no range change or angular data were obtained immediately after switch-over, so some error was introduced in the reduced AN/GMD-2 altitudes because of insufficient data at this point.

It was noted that in two of the flights, AS-J14-4 and AS-J18-8, shown in table IV, ranging deterioration of the radiosonde occurred at 100,000 feet and below. This may have been due to a gradual shift in ranging receiver center frequency to just beyond the bandwidth of the AN/GMD-2 transmitter.

Based on the information from table IV, the altitude accuracy of the AN/DMQ-6 - AN/GMD-2 system during parachute descent is probably within 1% of the true altitude down to 100,000 feet. Since these radiosondes were the first models produced, it is believed that improvements can be incorporated to provide better accuracy.

Table IV. RADIOSONDE AN/DMQ-6, ARÇAS ROCKET, RAWIN SET AN/GMD-2
Altitude vs Time Comparison during Parachute Descent

(Rawin Set AN/GMD-2 data independently reduced and compared with Radar AN/FPS-16 parachute track, except in Test AS-J18, where lock-in was necessary.

Weight suspended on parachute:
Tests AS-J15-6 7.25 lbs.
AS-J14-4 "
AS-J25-11 "
AS-J18-8 "
726011B 8 lbs
222005 "

Altitudes (in feet)

Time after launch (minutes)	AS-J15-6		AS-J14-4		AS-J25-11		226011B		222005		AS-J18-8	
	GMD-2	FPS-16	GMD-2	FPS-16	GMD-2	FPS-16	GMD-2	FPS-16	GMD-2	FPS-16	GMD-2	FPS-16
1.9			206580	204731								
2.0	213360	213090	207597	206470	207867	207868	197868					
2.1			207318	207263	205293	209079	200379		189453	189000		
2.2	210528	211310	205890	207014	199296	209339	195015				211770	211399
2.3			202557	205860								
2.4	205467	206318	200340	203910	191322	206785			184785		207807	208399
2.5	202449	203380	198156	201598			189399	lost track				
2.6					189765	201530			181272		202836	203210
2.7							179388				200034	200440
2.8			190818	193943	187638	195816						
2.9			188430	191448			168993					
3.0	189168	189829	185853	189051	185391	189952	164961	166500	172506	172600	lock-in	192416
3.1			183348	186770								
3.3									167427	168000		
3.5	178465	178998			174999	177357	156060	155600	163902	163800	180876	181380
3.9			168183	171335								
4.0	169437	169837			165957	167977	149220	149000	155685	156900		
4.5			164625	161994	158478	160818	144501	144000	149292	150700		
5.0	155118	155460			152121	154154	139410	138500	143313	145000		
5.5			151269	148910								
6.0	144093	144248			141096	143069	130815	130200	133455	135000	144195	145120
6.2			143964	141556								
7.0					132108	133887	124125	123800	125598	127000	135453	135577
7.1	133758	134046	136215	133535								
8.0	127245	127164			124920	126510	117912	117800	119916	120500	127983	127710
8.1			128532	126133								
9.0	120501	120653	122619	120202	118560	120221	112989	112100	113490	114600	121314	121028
9.5			119751	117331								
10.0	114924	114747			113004	114657	108273	108000	109245	109300	115455	115250
11.0	109665	109433			108240	109641	103194	103200	104343	104800	110697	110258
11.9	105663	105309										
12.0					103512	105322	100212	99400	99747	100500	106557	105760
12.5			105546	103129								
13.0	101127	100976	103419	101180	98217	101284	97773	96000	95202	96800	104352	101629
14.0	97773	97473			97239	97506	93249	92400	93021	93400	101847	97931
14.2			99294	96874								
15.0	94500	94157	96918	94222			89856	89800	89946	90300	99087	94661
15.1					92304	93921						
16.0	91476	90996			91377	91393	87246	87000	86985	87500	range change	
17.0	88713	88222			87255	88746	84756	84100	84048	84800	data during	
18.0	86274	85785			84687	86297	81852	82000	79107	82100	rocket flight	
19.0					82737	83945	80193	80000	76596	80000	not recorded	
19.1	83874	83273										

Tracking Comparison during Rocket Ascent

A time-altitude comparison was made with the radar skin-track of the rocket motor during the ascent phase of the flight. Although this information is not required for radiosonde-data reduction, it was requested by the Pacific Missile Range that these data be tabulated in order to obtain some measure as to how well the rawin set can be used to track a fast-moving beacon. The reduced data are shown in table V. These data were subject to the following sources of error in that this type of data reduction was not anticipated:

1. The paper speed of the graphic recorder was set at a slow rate, thereby compressing the sine wave recorded. This caused difficulty in reduction of range data.

2. Timing pulses were not recorded along with the range-change data, so it was difficult to associate the angular data recorded on the AN/GMD-2 control recorder with the range-change chart.

3. No time-synchronization with radar was available at the time of the tests; reaction-time errors were introduced. At a rocket speed of 3600 feet a second, this can be appreciable.

4. The elevation orientation accuracy of the AN/GMD-2 for each test was unknown.

In some cases, close agreement was obtained in spite of the above-listed conditions.

CONCLUSIONS

Radiosonde Set AN/DMQ-6 is at a level of development where, if an operational device of this type has field applications, limited production can be initiated. To meet performance levels demonstrated here, the laboratory modifications that were made should be included in the final instrumentation. For this reason, a model, drawings, and a suggested specification will be provided to the U. S. Army Electronic Materiel Support Agency, Fort Monmouth, New Jersey, should further requirements exist.

The foam plastic encapsulation technique will present problems in production, but this will be more than offset by the reliability achieved.

It is believed that this instrumentation can provide a self-sufficient, easily adaptable system for both operations and research.

ACKNOWLEDGMENTS

Valuable contributions of the following personnel and organizations are acknowledged:

Messrs. S. Thompson and R. Farley, Radar Division, USAELRDL, for development of the 1690-mc antenna.

TABLE V. RADIOSONDE AN/DMQ-6, ARCAS ROCKET, RAWIN SET AN/GMD-2
Altitude vs Time Comparison with FPS-16 Radar during Rocket Flight. (Altitudes in feet.)

26 November 1962

Time after launch (minutes)	Eglin Test AS-J25-11 GMD-2 altitude	Eglin Test AS-J25-11 FPS-16 altitude	Eglin Test AS-J15-6 GMD-2 altitude	Eglin Test AS-J15-6 FPS-16 altitude	Eglin Test AS-J14-2 GMD-2 altitude	Eglin Test AS-J14-2 FPS-16 altitude	Eglin Test AS-J14-4 GMD-2 altitude	Eglin Test AS-J14-4 FPS-16 altitude	PMR Test 226011B GMD-2 altitude	PMR Test 226011B FPS-16 altitude	PMR Test 222005 GMD-2 altitude	PMR Test 222005 FPS-16 altitude	Eglin Test 226011A GMD-2 altitude	Eglin Test 226011A FPS-16 altitude
.2	9027		12054	10851			12222	10349	10374		8142		9372	
.3	19881	19252	26427	23055	21459	21596	23991	21733	21405		18060	19500	21201	
.4	32811	32868	42579	40026	36699	36664	41430	37444	34275		30336	32300	35994	
.5			63834	64004			62427	57762	53826		48234	49600	56145	
.6	71157	70309	82044	79667	73899	72646	81231	76530	71853		68028	68000	74193	
.7	89109	87882	99438	96982			98619	93575	88677		84897	85200	90489	
.8	104790	104058			103095	101630	113697	109221	103386		99897	98500	105222	
.9			129828	127857	115515	114159	127857	123717	118689		113994	109000	118908	
1.0	133101	132760	143298	141541	126570	125520	140634	136944	131430		126438	121200	130785	127500
1.1	146694	145371	155745	154076	136902	135601	152532	149060	142254		137949	132000	141654	137200
1.2	158772	156825	166836	165491					153429		147951	142800	152472	148500
1.3	167496	167199	177201	175724	154167	152402	172872	169808	163482		157617	152700	162330	158000
1.4	177606	176398	186129	184853	160899	159098	181503	178441	171363		165840	161300	170058	165600
1.5	185697	184500	193623	192800	165459	164637	189180	185967	178890		172551	168500	177615	172600
1.6	191460	191344	201477	199603	171069	169040	195564	192456	183750		177720	174800	184038	179400
1.7	196818	197165	206697	205325	174417	172367	200724	197589	188892			180000	188799	184900
1.8	201846	201967			175731	174435	203904	201776	193389		184461	184000	192435	
1.9					177393	175302	206580	204731	196005			186800	195282	
2.0	207867	207868	213360	213090	175617	175126			197868		189060	188500	195654	
2.1									200379		189453	189000		
2.2									195015	194800	188571	188200		

Messrs. J. Kwik, H. Cozzens, and R. Irwin, Engineering Design Division, USAELRDL, for design and fabrication of time-delay unit and thermistor-mount assemblies.

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Commander W. Somervelle, Messrs. H. Keel and D. Swinton and USN AG1 D. Burtchin, for operations and facilities at the Pacific Missile Range.

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APPENDIX

Data-Reduction Technique

Telemetry. The blocking oscillator is calibrated at seven points with a 0.05% decade resistance box. A recording is obtained on Radiosonde Recorder AN/TMQ-5 with the recorder reference (obtained with zero resistance input) set to 90 divisions. A plot is made on a sheet of Keuffel and Esser No. 336P semilog paper of recorder division ratio vs resistance. A ratio with respect to the reference trace is used instead of direct frequency measurements, since the absolute pulse rate of the blocking oscillator drifts during a flight. Ratio data recorded during a flight can therefore be converted to resistance.

Temperature Sensors. A factory calibration of resistance vs temperature is provided with each sensor at -40°C, -15°C, and +10°C. Using the equations on pages 14 and 16, reference No. 1, the calibration is obtained from a programmed computer for every 1°C, or 0.1°C if desired, from -100° to +50°C. Before each flight, a record is made of the sensor serial number and sequence order in the commutator with respect to the reference trace which is obtained every 30 seconds, and the AN/TMQ-5 chart speed is recorded. After a flight, the data recorded on the AN/TMQ-5 are identified, the ratio obtained and converted to resistance, and the resistance is converted to temperature. Time-data are obtained from the AN/TMQ-5 by counting the number of inches from start, and associating this time with altitude data obtained from the ranging system.

Ranging Data. The ranging data consist of the ground distance between launcher and the AN/GMD-2; a sinusoid recorded on graphic recorder paper; and the range, azimuth angle, elevation angle, and time data recorded on Control Recorder C-1406. The number of cycles per second and fraction thereof is counted and multiplied by 2000 yards, and the result is added to the ground distance. A range reading of 100,000 yards is recorded on the C-1406 up to the time switch-over to automatic recording is accomplished. The range will either increase or decrease after switch-over is made.

The number of yards calculated from the graphic recorder chart and ground distance is multiplied by the sine of the elevation angle recorded at the time of switch-over in order to obtain the first altitude reading. The range used to obtain the first altitude reading is thereafter used as the reference range in computing altitude-time data from the C-1406 chart.

The following example is included for clarity:

Ground distance between launcher and AN/GMD-2, 5119 yards.

Number of cycles of range change recorded to switch-over time, 35.2 cycles.

C-1406 recorder readings at T + 2.0 minutes (time of switch-over).

Altitude	Range (yds)	Time (min)	Elevation Angle (degrees)	Azimuth Angle (degrees)
not used	100,270	2.0	70.49	178.74

Altitude (ft) = $\left[5119 + (35.2 \times 2000)\right]$ yds x sin 70.49° x $\frac{3 \text{ ft}}{\text{yd}}$ = 213,549.

C-1406 recorder readings at T + 3.0 minutes.

Altitude	Range (yds)	Time (min)	Elevation Angle (degrees)	Azimuth Angle (degrees)
not used	93.793	3.0	66.08	186.13

Range change, 100,270 - 93,793 = 6,477 yards decrease.

Range at 3.0 minutes, $\left[5119 + (35.2 \times 2000)\right]$ - 6,477 = 69,042 yards.

Altitude (ft) = 69,042 yds x sin 66.08 x $\frac{3 \text{ ft}}{\text{yd}}$ = 189,336 feet.

A condensed version of a typical range-change trace obtained during the rocket flight and recorded on a Minneapolis-Honeywell recorder, model 906, is illustrated in Fig. 16.

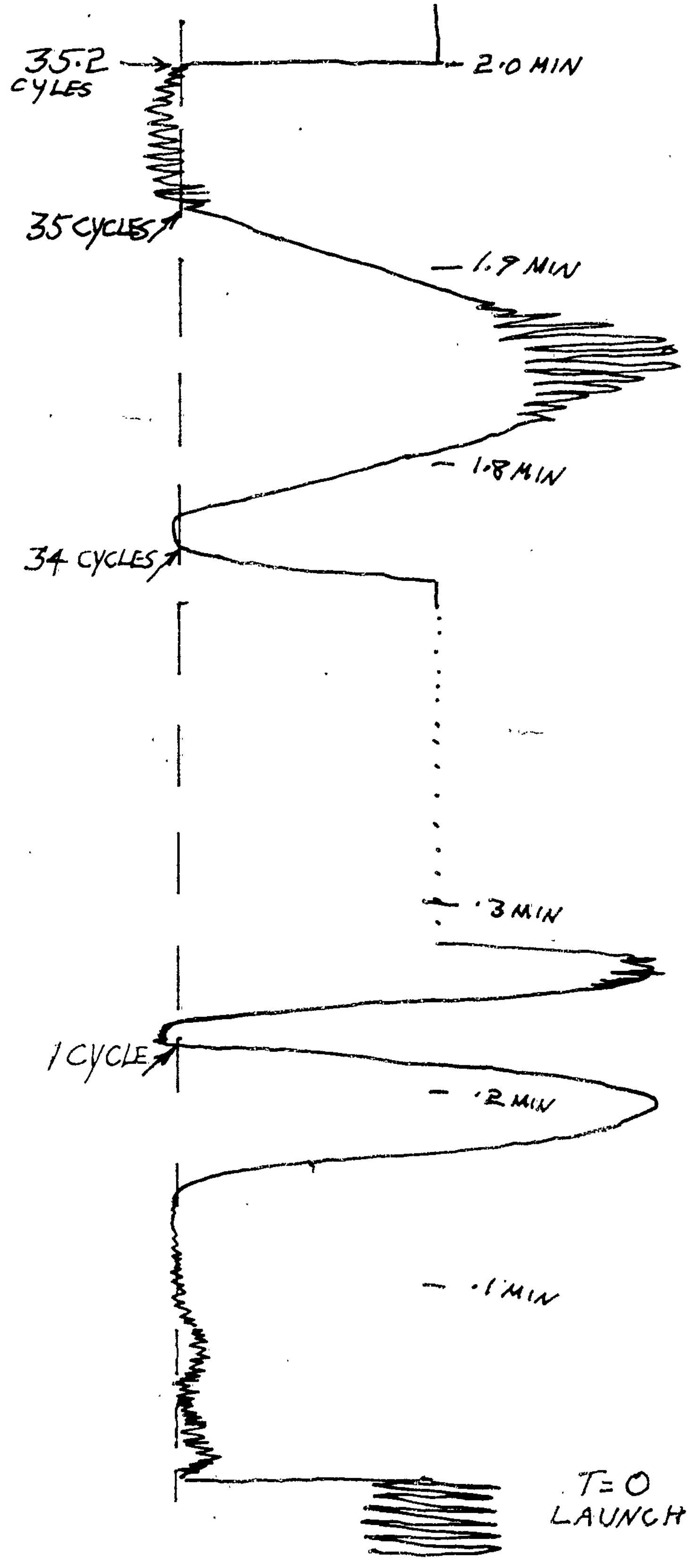

Fig. 16. Range-Change Trace from Test AS-J15-6

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(DA Task 3M36-21-001-01) Unclassified Report

Engineering flight tests were made on a system which included Radiosonde Set AN/DMQ-6, the ARCAS rocket, and Rawin Set AN/GMD-2. Temperature data were obtained with rod thermistors and bead thermistors. Data were obtained on a high-altitude hypsometer pressure sensor under development. Wind data were obtained and evaluated, and altitude data derived from the AN/DMQ-6 and Rawin Set AN/GMD-2 were compared with those obtained with the AN/FPS-16 radar. The altitude layer over which the data were obtained was between 80,000 and 210,000 feet. The test procedure used was that described in USASRDL Technical Report 2171.

Analysis of data obtained indicates useful temperature- and wind-data to 190,000 feet. Altitude data showed agreement within one percent or better with radar data.

1. Temperature data
2. Wind data

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